

Rosaceae—Rose family

Malus Mill.

apple

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Growth habit, occurrence, and use. The apple genus—*Malus* Mill.—includes about 25 species of deciduous trees or shrubs native to the temperate regions of North America, Europe, and Asia. Taxonomic classification of the native North American apples is the subject of active debate (Green 1996; Yanny 1996). Rehder (1940) recognized 9 native species—*M. angustifolia*, *M. bracteata*, *M. coronaria*, *M. fusca*, *M. glabrata*, *M. glaucescens*, *M. ioensis*, *M. lancifolia*, and *M. platycarpa*. Fiala (1994) suggests that, based on chromosome number, there are 3 distinct native species—*M. coronaria*, *M. fusca*, and *M. ioensis*. Other taxonomic structures having intermediate numbers of species have proponents (Green 1996). The nomenclature and occurrence of commonly recognized species are presented in [table 1](#).

Native apples and planted cultivars occur throughout much of North America. In general, apple performs best in full sunlight in deep, well-drained soils. Growth and vigor are best in rich sandy loams, but apple will grow well in heavier clay soils as long as they are well-drained (Fiala 1994). Ideal soil pH ranges from 5.5 to 6.5, but soils with pH in the range of 5.0 to 7.5 will support apple species (Fiala 1994).

The Oregon crab apple, the only native apple in western North America, occurs along the Pacific Coast from northern California to Alaska, occupying mesic to wet habitats at less than 800 m elevation (Hickman 1993). In California and Oregon, it occurs in open forests of the coast

ranges and the foothills of the Cascade Range (Hickman 1993). In British Columbia and southern Alaska, its range includes coastal climatic regions as well as zones of gradual transition to continental climate (Pojar 1996; Vierdeck and Little 1972). Oregon crab apple occurs as an early seral species occupying gaps within old-growth forests, as a component of estuarian and riparian complexes in major river valleys, and in upland Sitka spruce–red cedar swamps having locally perched water tables. In tidal marshes, it can form thickets as the dominant canopy species in association with grasses and forbs. It also occurs in the coastal fringe forest as scattered, slow-growing individuals on rocky shorelines and inland passages where it is protected from wind and salt spray. Oregon crab apple is somewhat tolerant of brackish water and short-term inundation.

In the upper mid-West of the United States, prairie and Great Lakes crab apples occur in open areas, on well-drained soils, near forest margins, in abandoned pastures, in oak savannahs, and at prairie margins (Kromm 1996; Little 1980; Yanny 1996). Common associates include shrubs of hawthorn (*Crataegus* spp.) and bur (*Quercus macrocarpa*) and black (*Q. velutina*) oaks. In southeastern Wisconsin, the native crab apples occur with greater frequency on clay and loam soils than on sandy soils. However, in contrast to Oregon crab apple, neither prairie or Great Lakes crab apples occur in wet areas (Kromm 1996).

In the southeastern United States, southern crab apple occurs at low altitudes on moist soils of valley bottoms and lower slopes. It is found in abandoned fields, along fence rows, and at forest margins, often forming dense thickets (Little 1980).

Native apples have served as a supply of food for both wildlife and humans. Indigenous peoples in both the eastern and western regions of North America have consumed crab apples (Pojar 1996; Vierdeck and Little 1972; Yarnell 1964). The occurrence of crab apples may be locally abundant in areas traditionally inhabited by indigenous peoples, but it is not known whether the trees were cultivated or grew from discarded fruit remains (Pojar 1996).

Consumption of fruit by birds and mammals is common. Known consumers include grouse (*Bonasa umbellus*), pheasant (*Phasianus colchicus*), rabbits (*Sylvilagus* spp.), squirrels (*Sciurus* spp.), opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), skunks (*Conepatus* spp.) and foxes (*Vulpes vulpes*) (Little 1980). The abundance of crab apples along fencelines and riparian areas is thought to reflect dispersal by wildlife. However, the large fruit size and

retention of the stem upon falling make transport by most species of frugivorous birds unlikely (Snow and Snow 1988). Observations suggest that deer may be the principal dispersal agent of crab apples in Europe (Snow and Snow 1988) and in southern Wisconsin (Kromm 1996).

Members of the apple genus have traditionally been some of our most important fruit bearers and ornamentals (table 1). Siberian crab apple has been used in shelterbelts. Larger stems of southern crab apple have been used to make tool handles. More recently, propagation of native crab apples has become increasingly important for habitat restoration (Callahan 1996) and apple cultivars have been considered for use in revegetation of minespoil (Brown and others 1983). Seedling propagation of native prairie crab apple as an ornamental is increasing in the mid-West as a means of avoiding the poorly adapted plants that can arise as sprouts from non-native rootstock following shoot girdling or browsing (Yanny 1996). Many cultivated varieties have been developed from the common or cultivated apple and from the Siberian crab apple, but these varieties are usually propagated vegetatively. Common apple and European crabapple are most often used as the rootstock for cultivars of crab apple (Fiala 1994).

Flowering and fruiting. The pink to white perfect flowers appear in the spring with or before the leaves. Flowering time varies among species from March to June (table 2). The fruit is a fleshy pome in which 3 to 5 carpels, usually 5, are embedded. Each carpel contains 2 seeds or 1 by abortion (figure 1) (Sargent 1965). Seeds have a thin lining of endosperm (figure 2), except in the cultivated, or common, apple, which has almost no endosperm (Martin 1946). Depending upon species, fruits ripen as early as August or as late as November (table 2). The fruits drop to the ground soon after ripening. Color of ripe fruit varies among the species (table 2).

Good crops of fruits and seeds generally occur every 2 to 4 years (Crossley 1974); however, good seed production has been observed annually for select stands of prairie crab apple in Wisconsin (Kromm 1996) and for many crab apple cultivars (Fiala 1994). Seed production may be negatively affected by late-spring frosts. The severity of frost effect on seed production depends on the stage of fruit development at the time of frost. Late-flowering cultivars of apple are less susceptible to fruit damage by late frosts than early and medium flowering cultivars (Nybom 1992). Cultivars of apple exposed to freezing temperatures during the pink to early-bloom stages of fruit development demonstrated seed abortion and fruit pedicle damage, but they continued to produce a smaller, but economically significant fruitcrop (Simons and Doll 1976).

A similar phenomenon has been observed in a wild stand of prairie crab apple, where a normal crop of crab apples were produced, yet the fruits bore no seeds (Kromm 1996).

Biennial bearing is a problem for commercial apple production (Williams 1989). Alternate-year fruit production arises from competitive effects of vegetative production, fruit development, and flowering. Trees bearing fruit with a large complement of seeds tend to initiate fewer flowers. Chemical methods, including the post-bloom application of thinning agents or growth regulators, have been successfully in manipulating fruit set and fruit quality (shape, firmness, russeting, and seed set) in commercial cultivars of apple (Greene 1989; Looney and others 1992; Williams 1989).

Collection of fruits; extraction and storage of seed. Ripe apples may be collected either by picking the fruits from the tree or by gathering fallen fruits from the ground (Crossley 1974). In contrast to domesticated varieties of apples, crab apples may persist in good condition on the ground for 2 to 3 weeks. Fruits from wild trees needs to be collected soon after they ripen, for wildlife may rapidly forage and deplete crops in the wild. Large amounts of seeds from domesticated apple cultivars may be extracted from cores obtained at food-processing plants (Richardson 1966). Seeds from cider mills, however, are often damaged (Crossley 1974) and may have a very low germinative capacity.

Accepted methods for seed extraction from the ripe fruits are cumbersome procedures involving combinations of after-ripening, mashing, and separation of pulp and seeds. After-ripening is the partial fermentation of the fruit. This can be done in a large container where the fruits are maintained at 10 to 18 EC for 2 to 4 weeks to soften (Callahan 1996; Nielsen 1988 [NOT IN REF LIST]). The softened fruits are then covered with water and mashed. The seeds may be sieved or left to settle out while the pulp is floated over the top with running water (Richardson 1966). Care should be taken to avoid high temperatures or excessive fermentation, as this may injure or kill the seeds (Heit 1967). Seeds may also be extracted by putting the fruits through a mechanical macerator (blender) with water, floating off the pulp, and then screening out the seeds (Nielsen 1988). Mechanical macerators or presses must be used with caution, as the seedcoats of apple species are thin and easily damaged, resulting in loss of germinative capacity. Extraction may be enhanced by carefully slitting the endodermis of the fruit before mashing (Yanny 1996). Wisconsin native populations of prairie and Great Lakes apples yield 1 to 2 and 3

to 4 viable seeds per fruit, respectively (Kromm 1996). The numbers of seeds per weight of fruit for various species are listed in [table 3](#).

Seed extracted in the above fashion can be sown immediately. If there is a need for overwintering, the seeds can be air-dried at room temperature for 3 months and then placed in refrigerator in a 50:50 sand and peat mixture for an additional 3 months. As with seeds of commercial varieties of apple, seeds from native crab apples may germinate in cold storage, resulting in difficult sowing.

Apple seeds are orthodox in storage behavior; long-term storage of seeds can be accomplished by drying the seedlot to lower moisture contents. Seeds dried to a moisture content less than 11% have been stored in a sealed container at 2 to 10 EC for over 2 years without loss of germinative capacity or seedling vigor (Solovjeva and Kocjubinskaja 1955). Decline in seed viability as a function of storage temperature and seed moisture content has been modeled for cultivars of cultivated apple (Dickie and Bowyer 1985). They determined that seedlots dried to 14.5% moisture content (fresh-weight basis) and stored at 6 EC lose half their viability in 323 days. With further drying to 5%, the estimated storage life increases to 37 years at 5 EC storage temperature or 100 years at 18 EC storage temperature (Dickie 1986).

Germination. Apple seeds display dormancy which has been overcome by cold stratification ([table 4](#)). Stratification is achieved by placing the seeds in a moist medium and storing at a temperature of 2 to 5 EC. A minimum of about 30 days under stratification conditions is required to remove embryonic dormancy (Zhang and Lespinasse 1991). After stratification, apple seeds exposed to diurnally alternating day/night temperatures of 30/20 EC, germinated in 30 to 60 days ([table 4](#)). Germination is epigeal ([figure 3](#)).

The application of growth-regulating chemicals, including gibberellin A₃ (GA₃), ethephon (E), and benzylaminopurine (BAP), has been used to obtain germination from non-stratified seeds (AOSA 1965; Litvinenko 1959; Sinska 1989; Zhang and Lespinasse 1991). Chemical treatments often involve soaking excised embryos in growth regulator solutions for periods of 1 to 24 hours. Variations in the concentration of growth substance and duration of soaking have significant impacts on both the percentage embryo germination and the quality of the resulting plants. Germination of nearly 100% of non-stratified embryos has been obtained with GA₃ applied at concentrations of 12.5 to 50.0 mg/liter for periods of 1 to 24 hours and with

BAP applied at 12.5 to 100 mg/liter for periods of 6 to 24 hours. Such treatments have resulted in 50 to 60% germination in less than 10 days and nearly 100% germination in 30 days (Zhang and Lespinasse 1991). Some plants produced from treated embryos demonstrate reduced growth, abnormally thick stems, or poorly developed roots. The percentage of abnormal plants produced tends to increase with increasing growth regulator concentration or increasing period of soaking. Successful application of growth regulator treatments as a substitute for stratification requires careful attention to protocol and is beyond the needs of most propagators as germination percentages of 90% or greater are commonly achieved using the relatively simple cold stratification process.

Nursery practice. Seedlings for use in landscape restoration or as apple rootstocks are often grown from seeds in nurseries (Richardson 1966; Callahan 1996). Untreated seeds have been sown in late fall (Bakke and others 1926; Callahan 1996; Kromm 1996; Yanny 1996) and stratified seeds have been sown in the spring (Crossley 1974; Yanny 1996). In a Washington nursery, seeds are stratified by first soaking them in water for 5 to 7 days, then placing sacks of seeds between layers of ice in a sawdust pit for 6 to 8 weeks. Seeds are subsequently dried only enough to flow freely through a mechanical planter (Crossley 1974). Seeds are sown in rows 20 cm (8 in) wide and 106 cm (42 in) apart (Davis 1940), 1.25 to 2.5 cm (½ to 1 in) deep on loose friable soil. A thin sawdust mulch aids seedling emergence on soils that form a crust after watering. Seedlings may be sprayed weekly with a fungicide to control powdery mildew. By the end of the growing season most of the seedling stems should be pencil-thick and about 38 cm (15 in) high (Richardson 1966). A height of 23 cm (9 in) is regarded as minimum size for grafting (Davis 1940). Most commercial varieties are propagated by budding or grafting onto seedling rootstocks (Crossley 1974; Fiala 1994; Richardson 1966; Solovjeva and Kocjubinskaja 1955).

In Wisconsin, crab apples for landscape use have been produced from seeds sown in the fall at a density of 270/m² (5/ft²) and covered with 2.5 cm (1 in) of sand. Apple **seeds** are among the first to germinate in the spring, often while soil temperatures are less than 4.5 EC, and **the seedlings** are generally hardy with respect to spring frost. Seedlings may be grown for 2 years without undercutting, reaching a size of 30 to 60 cm (1 to 2 ft) in height and a caliper of 1.25 cm (½ in) (Kromm 1996).

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Table 1— *Malus*, apple: nomenclature and occurrence

Scientific name & synonym(s)	Common name	Occurrence
<i>Malus angustifolia</i> (Ait.) Michx.	southern crab apple, narrow-leaf crab apple	SE US from Virginia to Florida & W to Mississippi
<i>Malus baccata</i> (L.) Borkh. <i>Pyrus baccata</i> L.	Siberian crab apple	Asia; planted extensively in US
<i>M. coronaria</i> (L.) Mill. <i>P. bracteata</i> Baily; <i>P. coronaria</i> L. <i>M. bracteata</i> (Baily) Rehd.	American crab apple, wild sweet crab apple, garland-tree	E US; New York to Alabama, W to E Indiana
<i>M. coronaria</i> var. <i>dasycalyx</i> Rehd. <i>P. coronaria</i> var. <i>dasycalyx</i> (Rehd.) Fern. <i>P. coronaria</i> var. <i>lancifolia</i> (Rehd.) Fern. <i>P. lancifolia</i> (Rehd.) Baily <i>M. coronaria</i> var. <i>lancifolia</i> (Rehd.) C.F. Reed <i>M. lancifolia</i> Rehd.	Great Lakes crab apple	S Ontario to Ohio & Indiana
<i>M. floribunda</i> Sieb. ex Van Houtte <i>M. pulcherrima</i> (Sieb.) Makino	Japanese flowering crab apple	Japan; planted extensively in E US
<i>M. fusca</i> (Raf.) Schneid. <i>P. rivularis</i> Dougl. ex Hook. <i>P. fusca</i> Raf. <i>M. diversifolia</i> (Bong.) M. Roemer	Oregon crab apple, Pacific crab apple, western crab apple, wild crab apple	Pacific Coast region from N California to S Alaska
<i>M. glabrata</i> Rehd.	Biltmore crab apple	SE US; North Carolina to Alabama
<i>M. glaucescens</i> Rehd. <i>P. glaucescens</i> (Rehd.) Baily	Dunbar crab apple	E US; New York to North Carolina & W into Alabama
<i>M. ioensis</i> (Wood) Britt. <i>P. ioensis</i> (Wood) Baily	prairie crab apple, Iowa crab apple, midwest crab apple	Minnesota & Wisconsin to Nebraska & Kansas & to Texas & Louisiana
<i>M. pumila</i> P. Mill. <i>P. pumila</i> (P. Mill.) Borkh. <i>M. communis</i> Poir <i>M. domestica</i> (Borkh.) Borkh.	common apple, apple, paradise apple	Europe & W Asia; cultivated horticulturally and agriculturally in US
<i>M. Hrobusta</i> (Carriere) Rehd. <i>M. baccata</i> <i>HM. prunifolia</i> (Willd.) Borkh.	red Siberian crab apple	Asia
<i>M. sargentii</i> Rehd.	Sargent apple	Japan
<i>M. sylvestris</i> P. Mill. <i>P. malus</i> L. <i>M. malus</i> (L.) Britt.	European crab apple, apple	Europe & W. Asia

Sources: Crossley (1974), Fiala (1994), Little (1980).

Table 2—*Malus*, apple: phenology of flowering and fruiting, color of ripe fruit, and height of mature trees

Species	Flowering dates	Fruit ripening dates	Color of ripe fruit	Height of mature trees (m)	Year first cultivated
<i>M. baccata</i>	May	Aug-Oct	Red or yellow	12.2	1784
<i>M. coronaria</i>	Mar-May	Sept-Nov	Yellow-green	9.2	1724
<i>M. floribunda</i>	May	—	Red or yellow	3.6–10.0	1862
<i>M. fusca</i>	—	Oct-Nov	Green-yellow to yellow & red	8–12.2	1836
<i>M. ioensis</i>	May-June	Sept-Oct	Greenish waxy	—	1885
<i>M. pumila</i>	May	Aug-Oct	Yellow to red	15.4	Ancient times
<i>M. Hrobusta</i>	Apr-May	—	Red or yellow-green	—	1815
<i>M. sargentii</i>	—	—	Red	1.8-2.5	—

Sources: Callahan (1996), Crossley (1974), Fiala (1994), Krüssmann (1960), Nielsen (1988), Rehder (1940), Sudworth (1908), Van Dersal (1938).

Table 3—*Malus*, apple: seed yield data

Species	Seeds/fruit wt		Cleaned seeds/fruit weight				Samples
	/100 kg	/100 lb	Range		Average		
			/kg	/lb	/kg	/lb	
<i>M. bacatta</i>	1.2	2.5	10,850-42,000	22,000-85,000	30,000	66,000	5
<i>M. coronaria</i>	0.5	1	—	—	6,350	14,000	1
<i>M. fusca</i>	1.2	2.4	—	—	24,500	54,000	1
<i>M. floribunda</i>	—	—	—	—	26,800	59,000	—
<i>M. ioensis</i>	—	—	—	—	13,600	30,000	1
<i>M. pumila</i>	0.4	0.75	3,460-13,300	7,000-27,000	9,100	20,000	5+
<i>M. Hrobusta</i>	—	—	—	—	7,700	17,000	—

Sources: Crossley (1974), Swingle (1939).

Table 4—*Malus*, apple: effects of cold stratification and germination test conditions on germination results

Species	Cold stratification (days)	Germination conditions			Germinative energy		Germinative capacity (%)	Samples
		Temp (EC)		Days	%	days		
		Day	Night					
<i>M. bacatta</i>	30	30	20	30	48	8	54	2
<i>M. coronaria</i>	120	10	10	30	93	19	96	1
<i>M. fusca</i>	90	—	—	—	—	—	—	—
<i>M. floribunda</i>	60–120	—	—	—	—	—	—	—
<i>M. ioensis</i> †	60	30	20	10	48	4	58	1
<i>M. pumila</i>	60	30	20	60	—	—	65	1+
<i>M. Hrobusta</i>	60–120	—	—	—	—	—	—	—

Sources: Crossley (1974), Heit (1967), Kallio (1962).

* In a moist medium at temperatures of 2 to 5 EC.

† In another test, fresh seeds from slightly green fruit were sown in a nurserybed without pretreatment and germinated 100%.

Figure 1—*Malus pumila*, common apple: seeds.

Figure 2—*Malus coronaria*, American crab apple: longitudinal section through a seed.

Figure 3—*Malus coronaria*, American crab apple: seedling development at 1, 3, 9, and 16 days after germination.